Possibilities for a Simple Study of the Time Structure of Hadronic Showers

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Calorimeter for ILC

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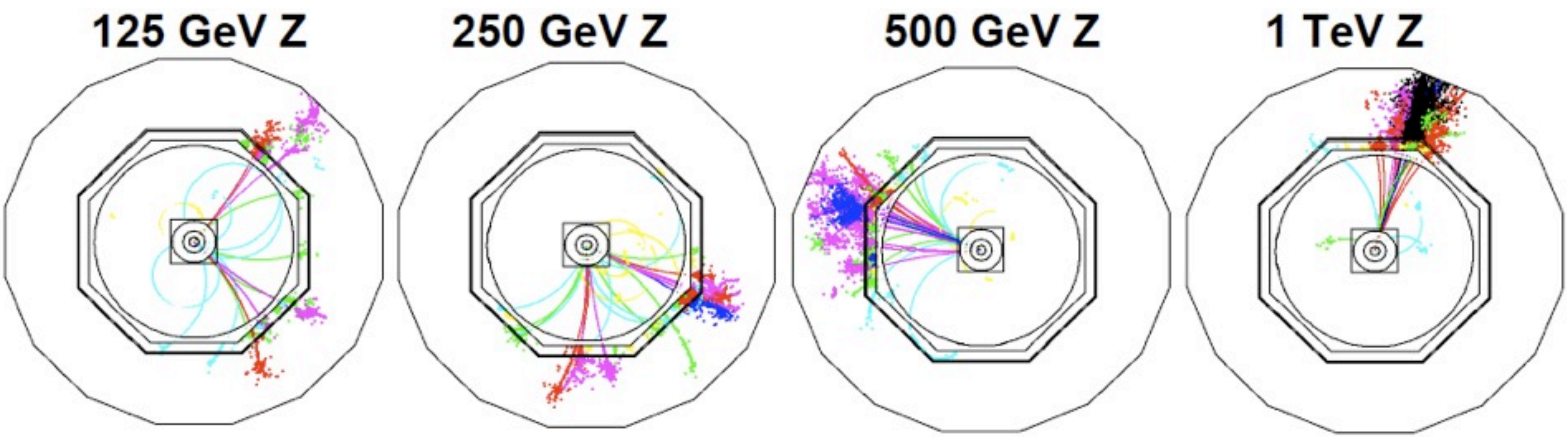
The Motivation: High Energy

- The Energy of the next LC is still unclear: Depends on what LHC finds!
  - A real possibility: Need a multi-TeV Collider instead of 500 GeV
  - The good news: We have a plan: CLIC
  - The challenge (for us): Calorimetry at a multi-TeV Collider is hard!



ILD-like detector, with 8 λ deep HCAL (M.Thomson, ALCPG09)

A key issue: Leakage! ➪ Deep HCAL required, potentially with a very dense absorber to satisfy the space constraints: Investigate Tungsten

Challenges for Calorimetry

- CLIC is different from ILC:
  - Very small bunch spacing: 0.5 ns ⇨ 2 GHz (!) bunch crossing rate
  - Short bunch trains: 312 bunches (165 ns) at 50 Hz
  - The challenge for calorimeters: $\gamma\gamma \rightarrow$ hadrons, ~ 3.3 events/BX, 13 particles/BX
- ▸ To avoid pileup and corresponding problems in the event reconstruction, good time resolution in all detectors (also in the calorimeters!) is needed: Current number: Better than 10 ns required

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How well does Tungsten work as an absorber for a PFA HCAL?

- Tungsten is very different from Steel:
- very different λ/X_0 ratio: em subshowers very short
- heavier nucleus: More neutrons in the shower

Material	Fe	W
λ_I [cm]	16.77	9.95
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Beam tests needed to answer the questions and to take on the challenges!

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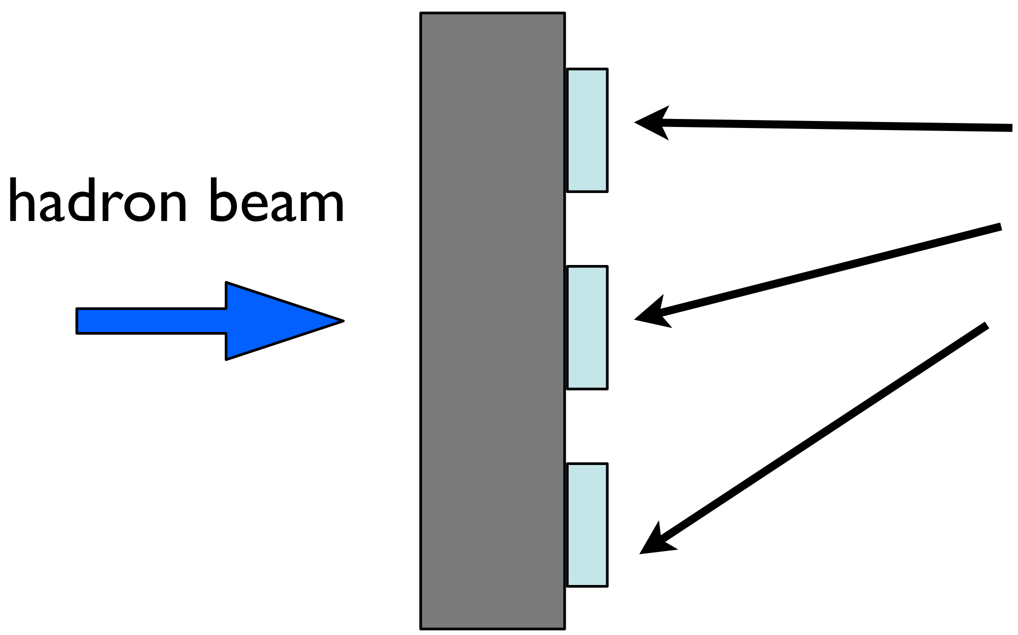
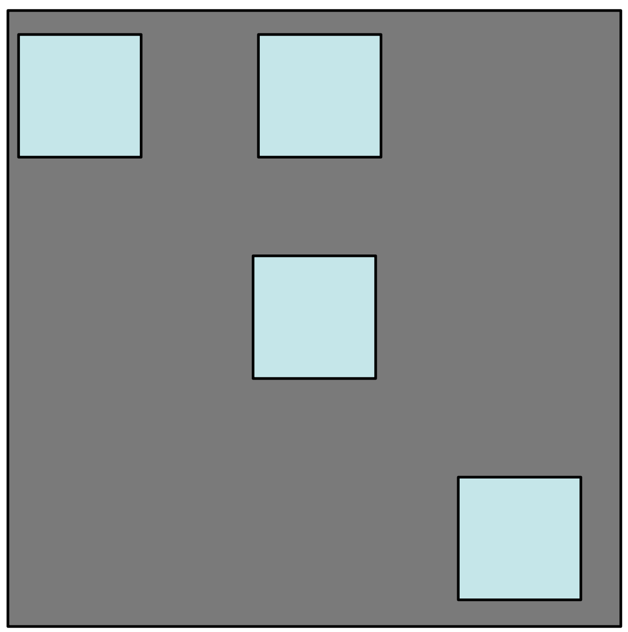
Investigating the Time Structure

- The long-term prospects: Full “4D” reconstruction with a completely instrumented W calorimeter and the new electronics: Will still take a while.
- The idea: Perform a simple study with only a very small number of channels



scintillator tiles, directly coupled MPPCs, read out with a fast Oscilloscope

central tile (maybe larger size?) also important as “multiplicity trigger”: Veto on non-showering particles



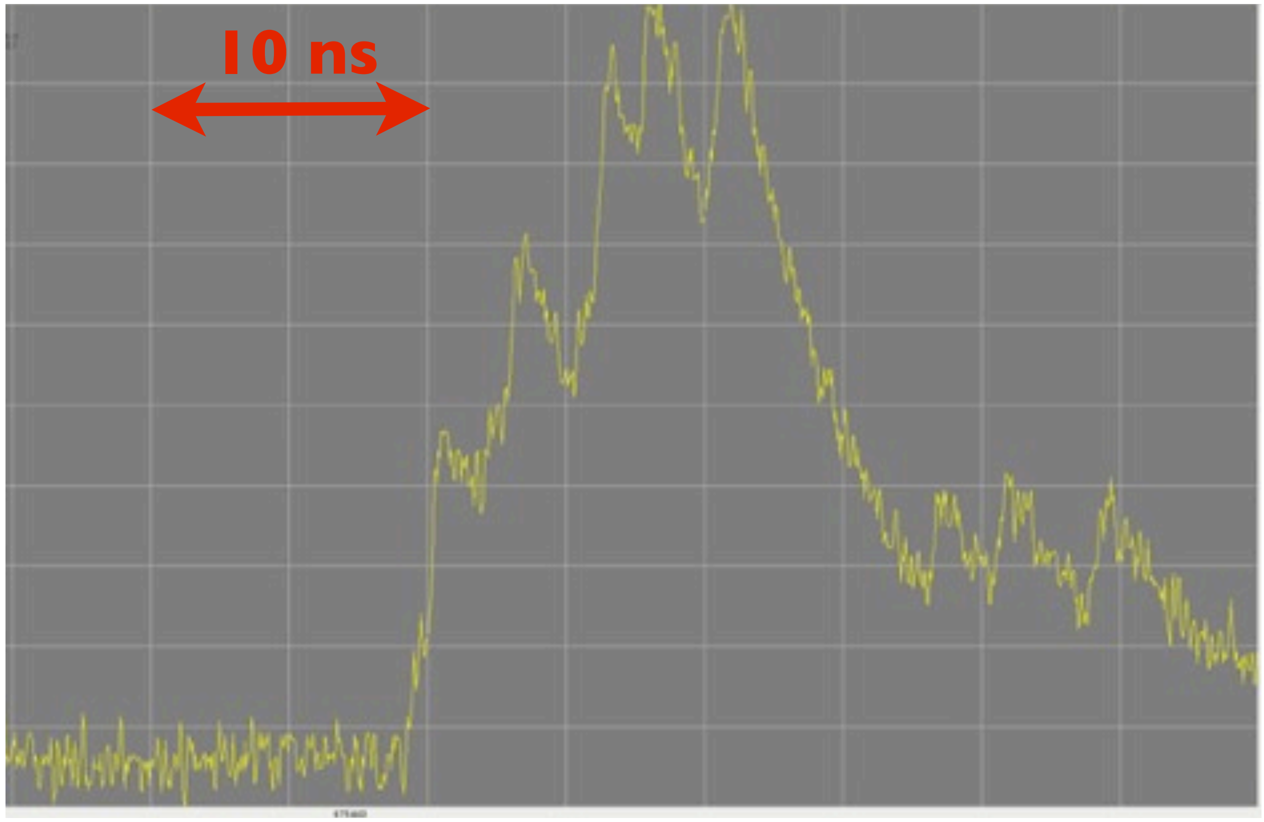
absorber: varying thickness, use both Fe and W

A possibility: Use absorber plates from Scintillator-W prototype: Almost 1 λ available
maybe also first absorber plates purchased by CERN?
Steel no real problem: Quite a few plates are around, and it is also relatively cheap to get...

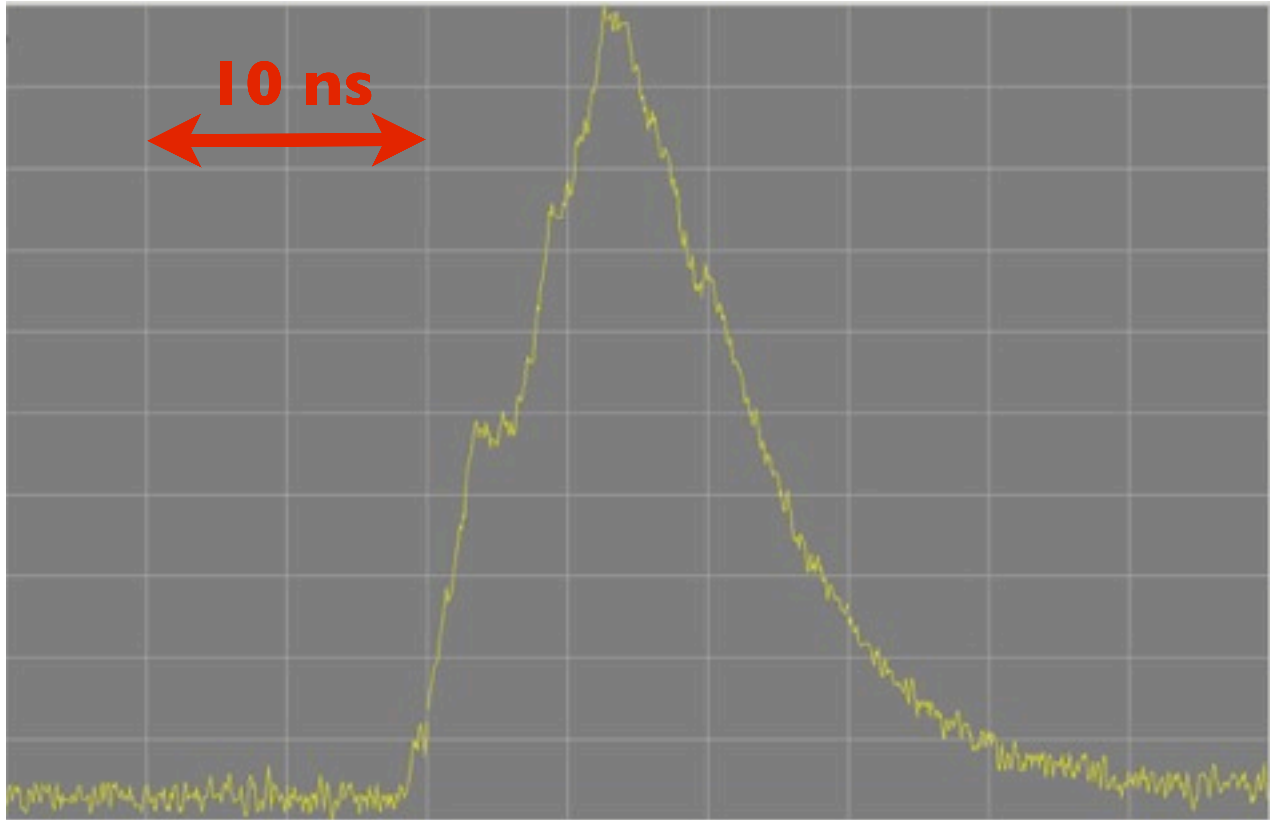
The Tools: Time-resolved Measurements

- A key issue: The time structure of the response of scintillator tiles
  - Measurements extracted from the direct coupling studies
  - ‣ With the high sampling (here actually more than needed) the arrival of every single photon on the SiPM can be identified

tile with WLS fiber



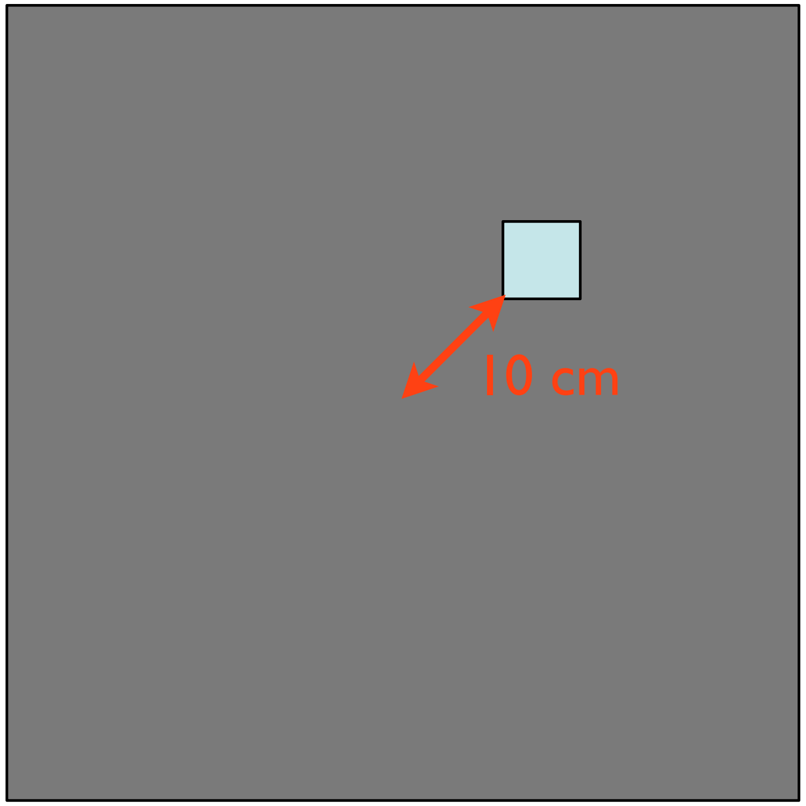
directly coupled tile



- Signal from directly coupled tile significantly faster: no delay due to absorption and reemission in WLS fiber

Quick Simulations to Test the Idea

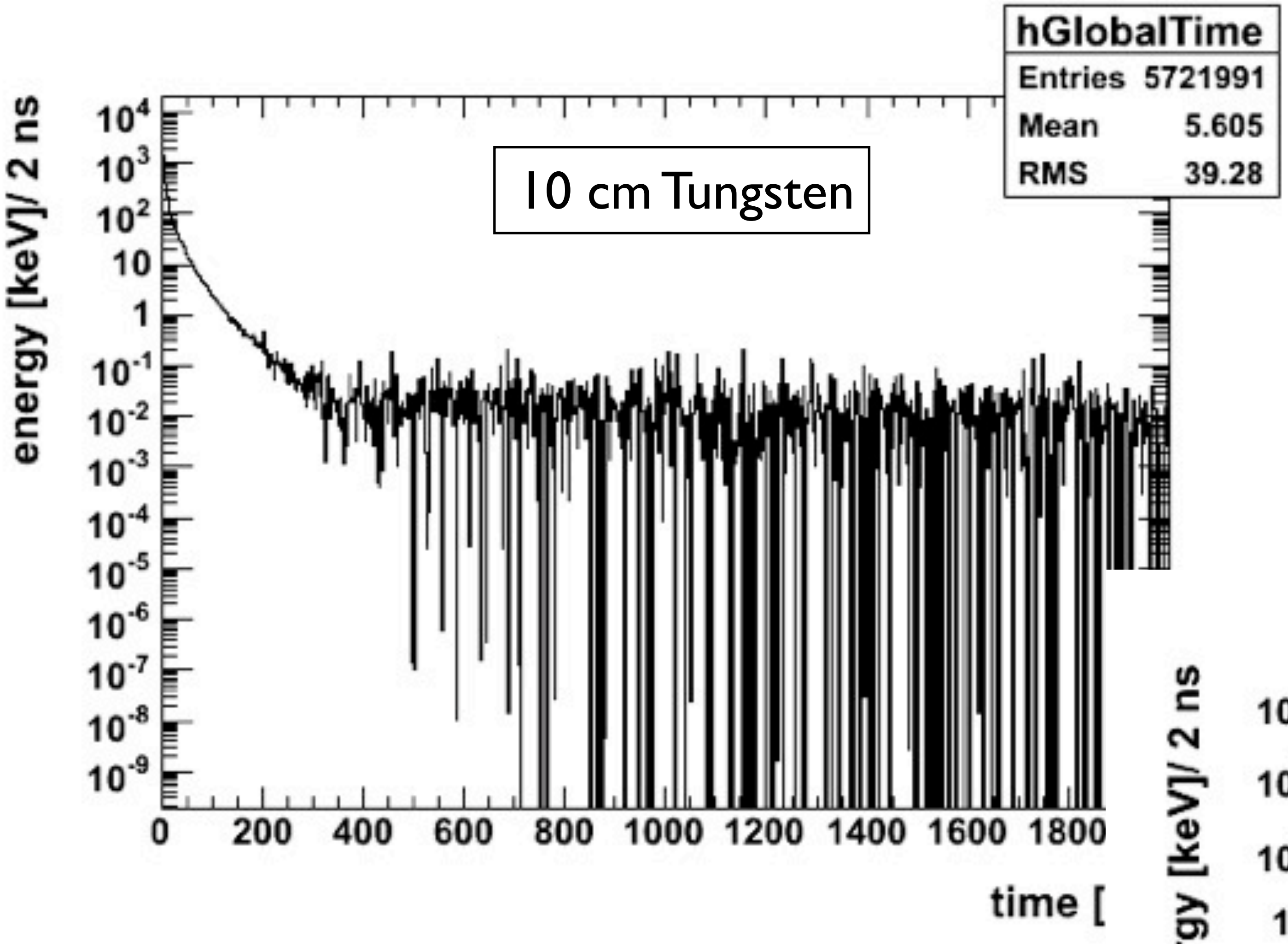
- Geant4 simulations, with 1 m^2 absorber of varying thickness, then 5 mm thick plastic scintillator
  - Physics List QGSP_BERT



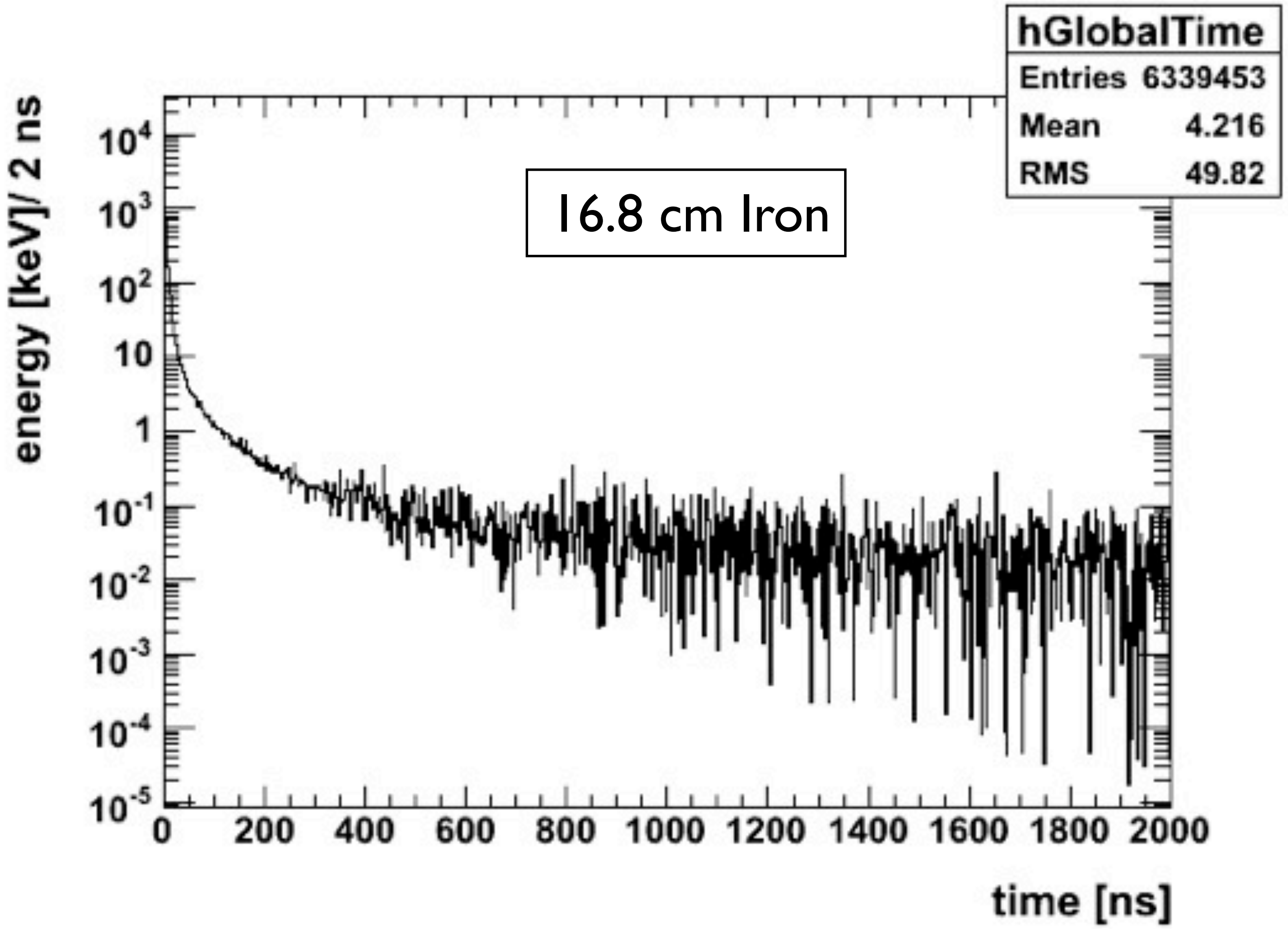
Distributions looked at:

- Time distribution of the energy deposits in the whole scintillator layer integrated
- Time distribution of energy deposits in a 3x3 cm^2 cell 10 cm from the beam axis
- Time distribution of the first energy deposit in the off-center cell for events which have more than ~0.4 MIP in that cell

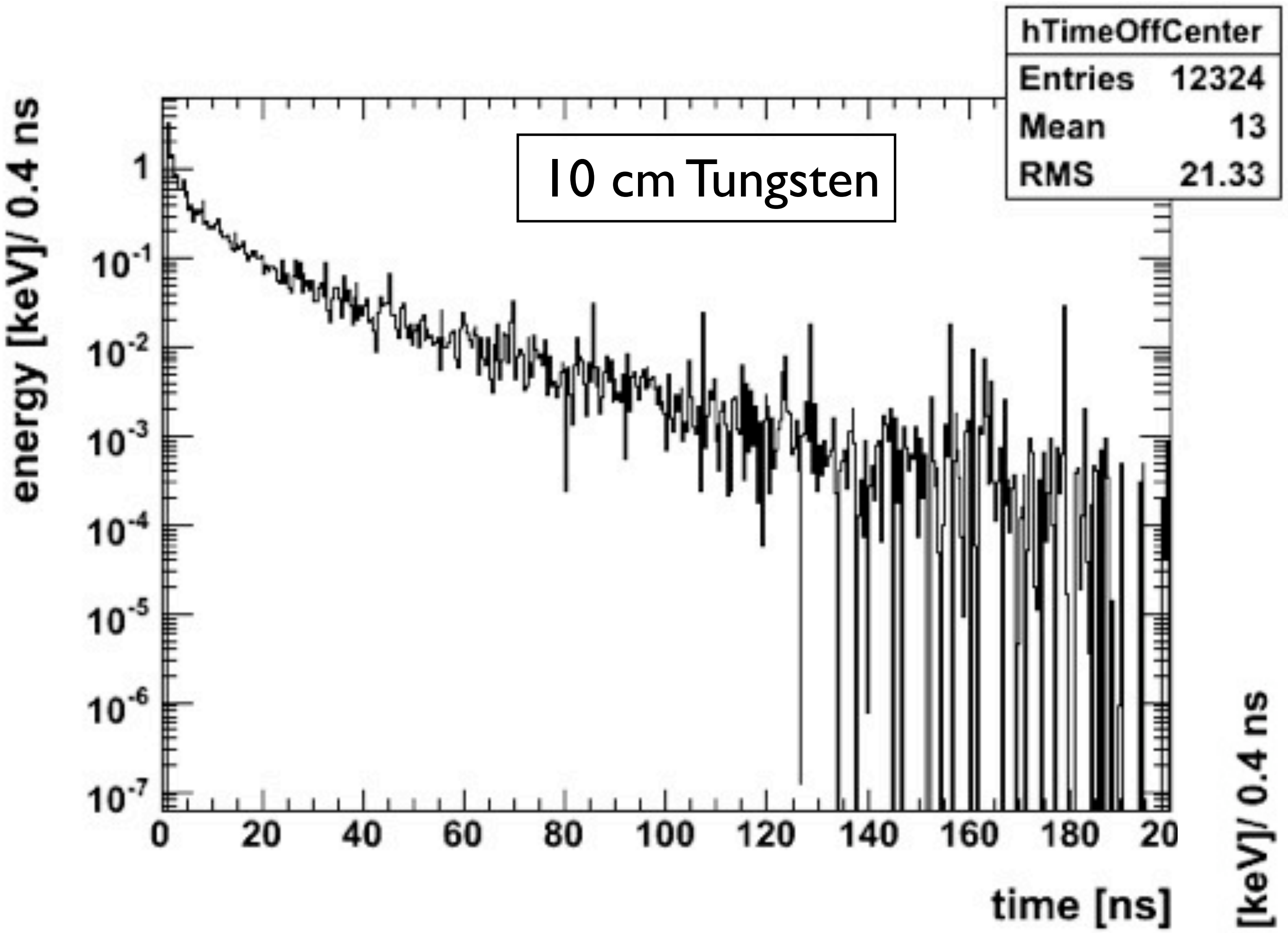
Simulation Results: Global Time Distribution

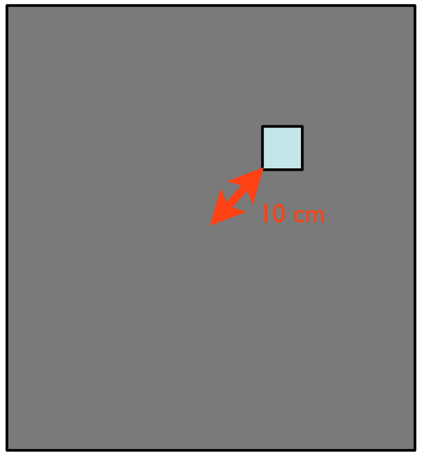


Time distribution of energy deposit in scintillator: 90% of all energy gets deposited in the first 10 ns for W (for 1 λ of Fe this is 97%)



Simulation Results: Time Distribution Off-Center

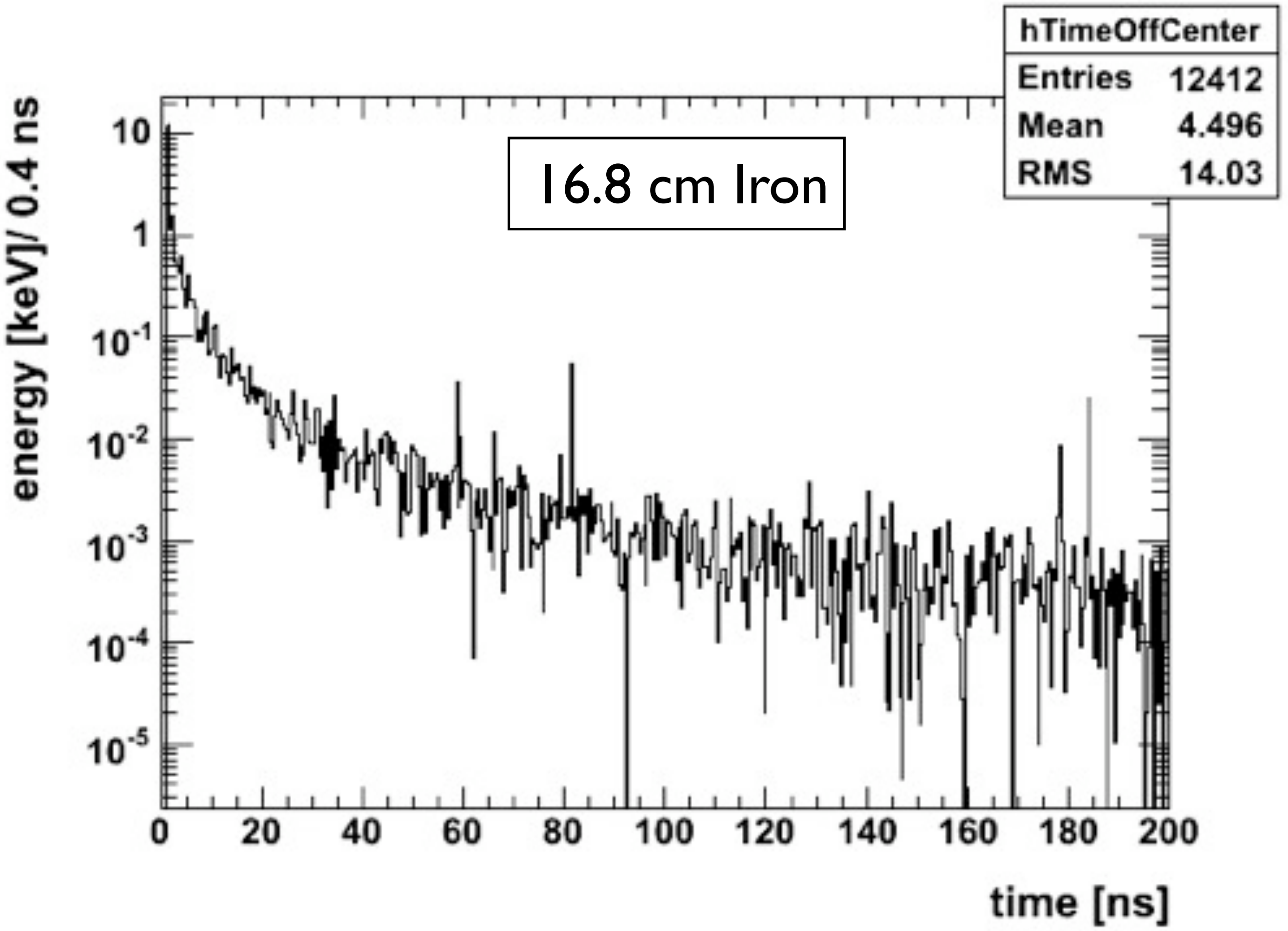




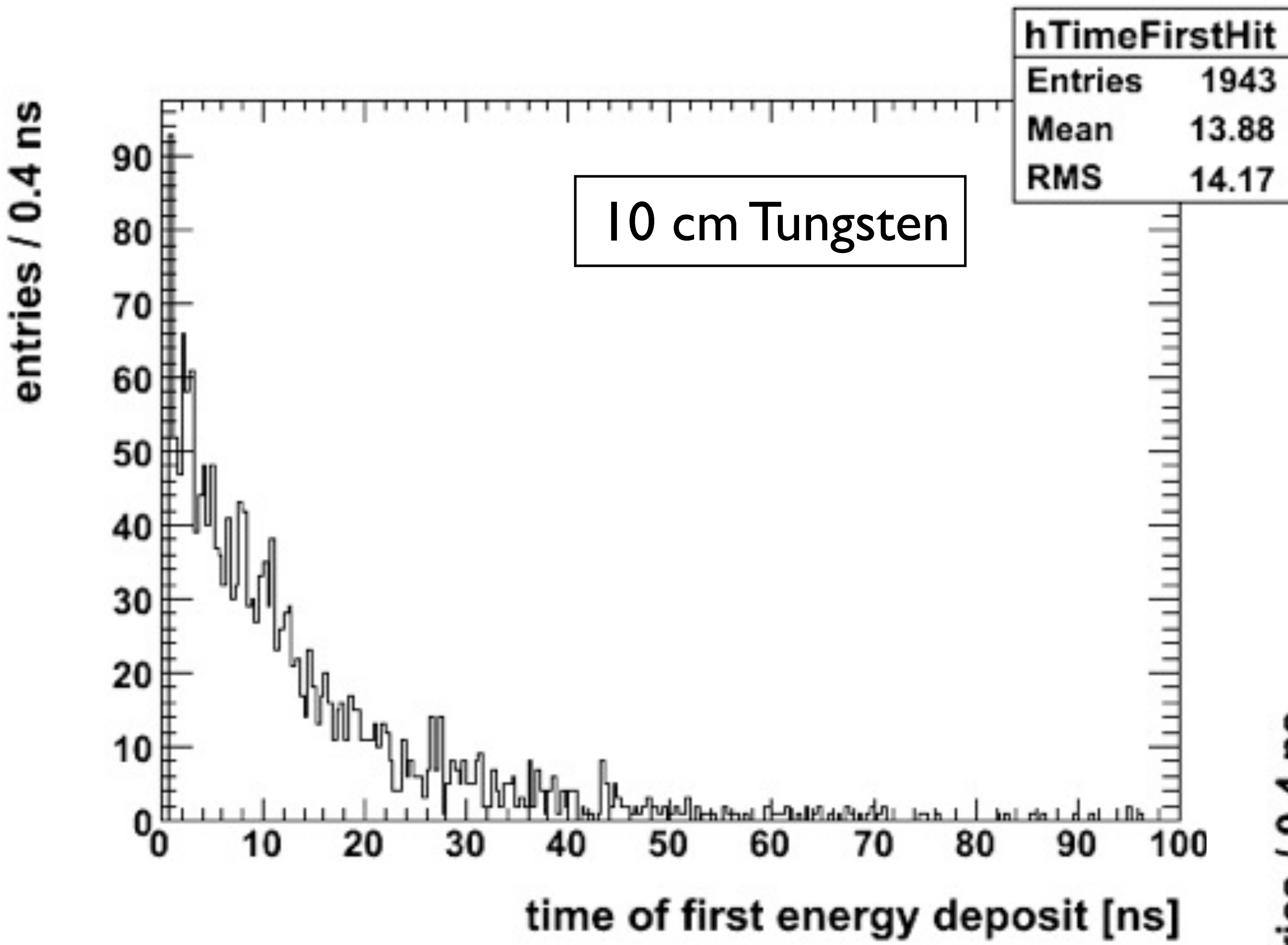
Time distribution of energy deposit in scintillator in a 3 x 3 cm^2 tile 120 mm from the beam axis:

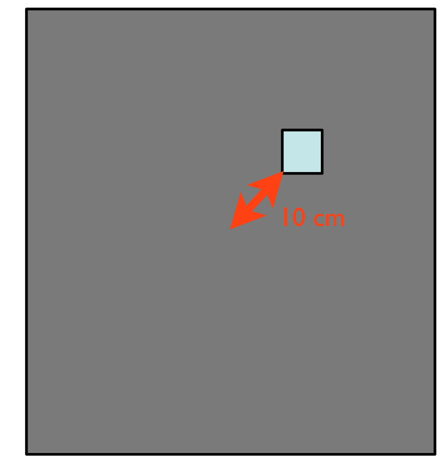
66% of all energy gets deposited in the first 10 ns (if the cell is hit at all)

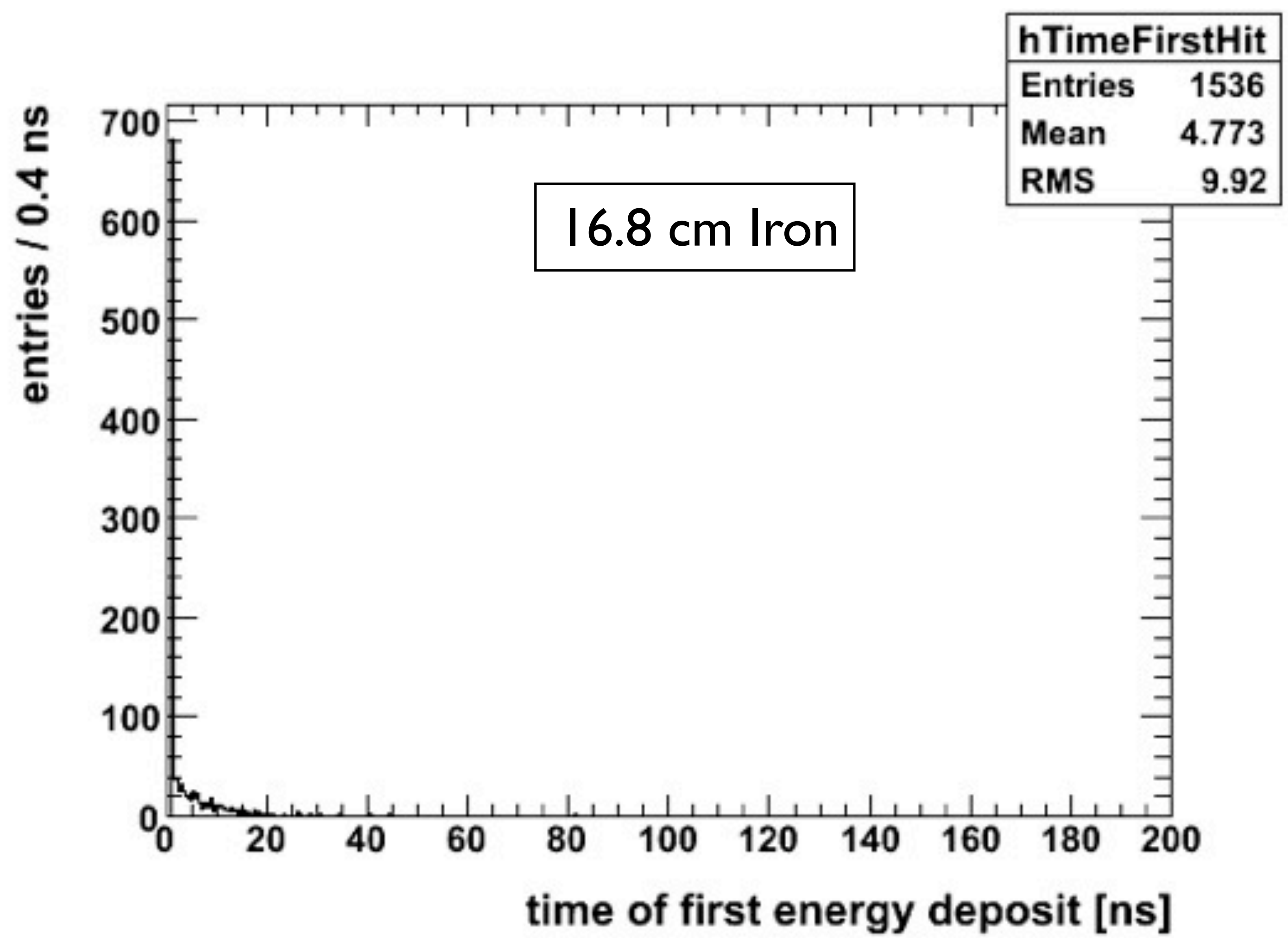
(for 1 λ of Fe this is 91.5%)



Simulation Results: Time of first Hit Off-Center







Time of the first energy deposit in scintillator in a 3 x 3 cm^2 tile 120 mm from the beam axis for hits that have a total of more than ~0.4 MIP: 52% of all hits start in the first 10 ns (if the cell is hit at all)

(for 1 λ of Fe this is 86%)

The Energy and Absorber Thickness Dependence

- From 5 to 20 cm W absorber (10 GeV):
  - Total energy in the first 10 ns: 97% ⇨ 79%
  - First energy deposit off-center in first 10 ns: 71% ⇨ 46%

- From 10 to 30 GeV (10 cm W absorber):
  - Total energy in the first 10 ns: 90% ⇨ 94%
  - First energy deposit off-center in first 10 ns: 52% ⇨ 53%

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  - Total energy in the first 10 ns: 97% ⇨ 79%
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- From 10 to 30 GeV (10 cm W absorber):
  - Total energy in the first 10 ns: 90% ⇨ 94%
  - First energy deposit off-center in first 10 ns: 52% ⇨ 53%

Precise beam Energy not very important! Experiment can be performed parasitically with other CALICE test beams.
Required statistics reasonably modest, max event rate needs to be investigated

Summary

- For a Multi-TeV LC, leakage is a serious concern for the calorimeter system
  - A dense absorber is attractive: Tungsten!
- CLIC has extremely high bunch crossing rates (2 GHz) and considerable hadronic background from $\gamma\gamma$ interactions
  - Time stamping of signals is crucial for background rejection

- Simulations for Tungsten have very large uncertainties: Needs to be improved by test beams
  - Timing is definitely a crucial open issue
- With a simple beam test, some valuable information can already be gained about the time structure of hadronic showers in Tungsten

- A full study requires a completely instrumented W HCAL